

MISSISSIPPI DOT'S PLAN TO IMPLEMENT THE 2002 DESIGN GUIDE

FINAL REPORT

by

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conducted by

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APPLIED RESEARCH ASSOCIATES, INC.**

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MISSISSIPPI DEPARTMENT OF TRANSPORTATION

and the

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<p>16. Abstract</p> <p>Applied Research Associates, Inc., ERES Consultants Division, is finalizing the development of the 2002 Guide for Design of New and Rehabilitated Structures through National Cooperative Highway Research Program (NCHRP) Project 1-37A. Anticipated submission of the Design Guide to NCHRP is in fall 2003.</p> <p>The Mississippi DOT has taken a proactive approach for implementing the Design Guide. 2002 Design Guide implementation activities at Mississippi DOT include becoming familiar with the procedure and training of staff, developing an implementation plan, conducting initial material tests on hot mix asphalt (HMA), developing a traffic estimation procedure, and selection of field sections for use in local calibration of the procedure.</p> <p>The 2002 Design Guide, which uses mechanistic-empirical (ME) principles for pavement design, offers benefits that include:</p> <ul style="list-style-type: none"> • More comprehensive pavement design • Improved pavement life and design reliability • Improved consideration of new materials and design features • More cost-effective designs • Enhanced capability to conduct failure or forensic analyses <p>The Mississippi DOT is implementing the design guide in two phases. An implementation plan is developed in Phase I, and actual implementation of the Design Guide occurs in Phase II. Phase I (current research) included:</p> <ul style="list-style-type: none"> • Familiarization of Mississippi DOT staff with the 2002 Design Guide • Discussions and meetings to establish the scope of pavement types and rehabilitations that Mississippi DOT is interested in • Development of a factorial experiment design • Recommendation of test sections for calibration and validation of the performance models • Preparation of a detailed plan for Phase II implementation • Estimation of a budget for implementing the 2002 Design Guide <p>The Phase II work plan, to be conducted over a period of five fiscal years, includes the following research tasks:</p> <ul style="list-style-type: none"> • Conduct a detailed review of all design inputs • Conduct an initial sensitivity analysis and comparison with current Mississippi DOT procedures • Provide guidance to carry out the required field and laboratory testing • Outline work related to obtaining all design inputs including detailed traffic inputs, selection of performance criteria, and material testing • Establish default inputs where applicable • Calibrate and validate the distress prediction models with Mississippi pavement performance data • Conduct additional sensitivity analysis and comparison of the 2002 Design Guide procedure with current Mississippi DOT design procedure results • Prepare detailed design and training manuals for training and future reference • Customize the Design Guide software to include Mississippi-calibrated performance models and default inputs • Provide training to Mississippi DOT staff 					
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Drs. Saeed and Hall prepared this report.

DISCLAIMER

The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those of the Mississippi Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

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ABSTRACT

Applied Research Associates, Inc., ERES Consultants Division, is finalizing the development of the 2002 Guide for Design of New and Rehabilitated Structures through National Cooperative Highway Research Program (NCHRP) Project 1-37A. Anticipated submission of the Design Guide to NCHRP is in fall 2003.

The Mississippi DOT has taken a proactive approach for implementing the Design Guide. 2002 Design Guide implementation activities at Mississippi DOT include becoming familiar with the procedure and training of staff, developing an implementation plan, conducting initial material tests on hot mix asphalt (HMA), developing a traffic estimation procedure, and selection of field sections for use in local calibration of the procedure.

The 2002 Design Guide, which uses mechanistic-empirical (ME) principles for pavement design, offers benefits that include:

- More comprehensive pavement design
- Improved pavement life and design reliability
- Improved consideration of new materials and design features
- More cost-effective designs
- Enhanced capability to conduct failure or forensic analyses

The Mississippi DOT is implementing the design guide in two phases. An implementation plan is developed in Phase I, and actual implementation of the Design Guide occurs in Phase II. Phase I (current research) included:

- Familiarization of Mississippi DOT staff with the 2002 Design Guide
- Discussions and meetings to establish the scope of pavement types and rehabilitations that Mississippi DOT is interested in
- Development of a factorial experiment design
- Recommendation of test sections for calibration and validation of the performance models
- Preparation of a detailed plan for Phase II implementation

- Estimation of a budget for implementing the 2002 Design Guide

The Phase II work plan, to be conducted over a period of five fiscal years, includes the following research tasks:

- Conduct a detailed review of all design inputs
- Conduct an initial sensitivity analysis and comparison with current Mississippi DOT procedures
- Provide guidance to carry out the required field and laboratory testing
- Outline work related to obtaining all design inputs including detailed traffic inputs, selection of performance criteria, and material testing
- Establish default inputs where applicable
- Calibrate and validate the distress prediction models with Mississippi pavement performance data
- Conduct additional sensitivity analysis and comparison of the 2002 Design Guide procedure with current Mississippi DOT design procedure results
- Prepare detailed design and training manuals for training and future reference
- Customize the Design Guide software to include Mississippi-calibrated performance models and default inputs
- Provide training to Mississippi DOT staff

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Applied Research Associates, Inc., ERES Consultants Division, is finalizing the development of the 2002 Guide for Design of New and Rehabilitated Structures through NCHRP Project 1-37A¹. Anticipated submission of the Design Guide to NCHRP is in the fall of 2003.

The 2002 Design Guide incorporates ME pavement design principles and is a vast improvement over current empirical pavement design procedures. Implementation of the new procedure will require a well-thought-out implementation plan to make the transition as smooth as possible. This would require an agency to undertake, at least, the following three tasks:

- Secure upper management support to obtain necessary resources and authority to implement the new design procedure
- Assemble a steering committee of stake holders to champion the implementation
- Develop an implementation plan

Both highway users and highway agencies will benefit from the successful implementation of the 2002 Design Guide. Highway agencies will be able to develop cost-effective and reliable designs by systematically considering climate, material properties, construction variability, and traffic to predict pavement performance. This will allow highway agencies to reduce pavement failures. The NCHRP 1-37A project team has estimated that highway agencies could save approximately \$1.3 billion per year if the new procedure is only half as effective as expected. These savings result from pavement designs that produce only a 10 percent increase in performance. The highway users could save up to \$350 million per year just on the interstate highway system from increased smoothness, fewer lane closures, and less congestion².

Considering all the benefits, Mississippi DOT is one of the few highway agencies that are proactively pursuing the implementation of the 2002 Design Guide. Current activities at Mississippi DOT for implementing the 2002 Design Guide include research to develop an implementation plan for the new procedure, familiarizing personnel with the ME pavement design principles, and selection of appropriate procedures and testing to obtain the many design inputs.

This report describes the research conducted to develop an implementation plan for Mississippi DOT through State Study 163³, “Develop Mississippi DOT’s Plan to Implement the 2002 Design Guide.”

1.2 RESEARCH OBJECTIVE

The Mississippi DOT is implementing the 2002 Design Guide in two phases. The main objective of Phase I research was to develop a “road map” or plan for the Mississippi DOT’s implementation of the 2002 Design Guide. Actual implementation of the new design procedure will take place in Phase II.

The implementation plan (Phase I) identified the specific steps that the Mississippi DOT will need to take to implement all aspects of the 2002 Design Guide of interest. Phase I research included the following tasks:

- Familiarize Mississippi DOT staff with the 2002 Design Guide
- Identify Mississippi DOT needs relative to the types of pavements of interest for new or reconstruction design and the types of rehabilitation for existing pavements
- Develop a calibration and validation plan to modify the 2002 Design Guide performance model for Mississippi conditions
- Develop factorial experiment design and select test sections
- Recommend technology transfer procedures and a personnel training program
- Prepare a detailed plan or “road map” for implementation of the 2002 Design Guide
- Prepare Phase II work plan and estimated costs

1.3 REPORT ORGANIZATION

Chapter 2 provides a brief introduction to the 2002 Design Guide pavement performance models that are a most important component of the new procedure. Chapter 3

discusses the factorial experiment design used to select test sections to calibrate and validate the performance models for Mississippi conditions, and Chapter 4 discusses the calibration validation procedure. Chapter 5 proposes a number of technology transfer activities that could be used to familiarize and train Mississippi DOT personnel to the new procedure. Chapter 6 provides the Phase II work plan and an estimated budget. Chapter 7 summarizes Phase I research and includes some recommendations.

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CHAPTER 2

2002 DESIGN GUIDE PERFORMANCE MODELS

2.1 PAVEMENT PERFORMANCE

The 2002 Design Guide considers both the functional and structural performance of pavements. The structural performance of a pavement relates to its physical condition in terms of distresses and other conditions that would reduce its load carrying capabilities. The functional performance, on the other hand, relates to how well the pavement serves the user. The 2002 Design Guide uses the International Roughness Index (IRI) as the functional performance index. Typically, initial IRIs are in the range of 50–100 in/mile and terminal IRIs are in the range of 150–200 in/mile.

Pavement distresses (cracking, rutting, faulting, etc.) are a function of pavement design, construction materials, traffic, age, foundation (subgrade), and climate. Pavement smoothness is determined from the severity and extent of all the distresses. The 2002 Design Guide uses a cumulative model for IRI (smoothness) where all the subsequent increases in roughness (due to distresses) are added to the initial as-constructed roughness. This is to say that roughness will increase due to initiation and increase in individual distresses, due to changes in site conditions and maintenance activities. The roughness model used in the 2002 Design Guide has the form:

$$S_T = S_O + (a_1 S_{D(T)1} + a_2 S_{D(T)2} + a_3 S_{D(T)3} + \dots + a_n S_{D(T)n}) + b_J S_J + c_J M_J$$

where:

- S_T = Pavement smoothness at a specific time, T (IRI, in/mile)
- S_O = Initial as-constructed roughness (IRI, in/mile)
- $S_{D(T)(i = 1 \text{ to } n)}$ = Change in smoothness due to i^{th} distress at a given time T
- S_J = Change in smoothness due to site factors (subgrade, age)
- M_J = Change in smoothness due to maintenance activities
- $a_{(i = 1 \text{ to } n)}, b_J, C_J$ = Regression constants

2.2 FLEXIBLE PAVEMENT PERFORMANCE MODELS

The 2002 Design Guide considers three primary distress and other factors to predict the smoothness of flexible pavements at any given time¹:

- Load-associated fatigue cracking
- Thermal cracking
- Permanent deformation (rutting)

The 2002 Design Guide procedure estimates the distress for each analysis interval and accumulates it for the analysis period. The analysis interval is usually 1 month, except for the freeze-thaw period when it is reduced to 2 weeks because of the potential of rapid changes in modulus (due to changes in temperature and moisture condition).

These models are described briefly here. Only the final form of the models is provided. The reader is encouraged to review publications originating from the research associated with the development of the 2002 Design Guide to obtain detailed information about these models¹.

2.2.1 Load-Associated Fatigue Cracking of AC Layer

One of the major distresses of flexible pavements is load-associated fatigue cracking. Tensile and shear strains due to repeated traffic loads cause a reduction in structural integrity of bound pavement layers, leading to crack initiation at critical locations. The location of crack initiation depends on a number of factors, the most important of which are mix stiffness and geometry of the applied loads. Once a crack appears in the bound layer, the repeated action of traffic loads causes it to propagate through the entire thickness of the bound layer. Fatigue cracking is not only a surface layer problem but can also occur in bound underlying layers, such as cement stabilized base layers. Cracking in underlying layers reduces the overall structural capacity of the pavement system and causes reflective cracks to appear in the surface layer.

The 2002 Design Guide considers both the classic concept of fatigue cracking initiating at the bottom and propagating upwards and the more recent theory of fatigue cracking developing at the surface and propagating downwards. The bottom-up fatigue cracking results from flexural stresses at the bottom of the bound layer, which is why almost all ME pavement design procedures try to limit the strains at the bottom of the bound

pavement layers. Top-down fatigue cracking, on the other hand, results from tensile and shear stresses at the surface due to large contact pressures at the edge of tires.

The 2002 Design Guide model for prediction of fatigue cracking is a function of both stiffness of the mix and tensile strain at the bottom of the asphalt concrete (AC) layer. The selected model recognizes that fatigue cracking is more likely when the modulus of AC is high, as would be the case in cold climates or for oxidized pavements. The number of stress repetitions to fatigue failure (N_f) is given by¹:

$$N_F = \beta_{F1} F'' K_1 (\epsilon_T)^{-K_2} \beta_{F2} (E)^{-K_3} \beta_{F3}$$

where:

N_F = Number of repetitions to fatigue cracking

F'' = $1 + (F \div (1 + \exp^{(1.354 h_{AC} - 5.408)}))$

F = $13909 E^{-0.4}$

ϵ_T = Tensile strain at the critical location

E = Material stiffness

K_1, K_2, K_3 = Equation coefficients

$\beta_{F1}, \beta_{F2}, \beta_{F3}$ = Calibration factors

The calibration factors are held constant at 1 and could be changed for State or local calibration. For national calibration, equation coefficients K_1 , K_2 , and K_3 are 1, 5, and -1.4, respectively.

Fatigue behavior of asphalt can be characterized using tests conducted at constant strain or constant stress. Thick pavement layers, usually more than 8 inches, are characterized using a constant stress type of loading. The constant strain type of load is generally applicable to thin pavement layers, usually less than 2 inches thick. For intermediate thickness, fatigue life is governed by a combination of constant stress and constant strain. The factor F relates the ratio between the constant stress and constant strain and is a function of the modulus of the AC material. The sigmoidal function F'' provides a continuous relationship as a function of F and thickness.

2.2.2 Thermal Cracking of AC Layer

The 2002 Design Guide thermal cracking model is based on research conducted through several NCHRP research projects. The approach uses the Enhanced Integrated Climatic Model (EICM) to estimate a temperature-depth profile for the AC layer for each hour of the analysis period. The thermal analysis procedure is based on linear viscoelastic principles and requires data from the creep compliance test conducted at three temperatures (0, -10, -20 °C) or one temperature, depending upon the level of analysis and indirect tensile test conducted at -10 °C. Data from these tests are used to relate creep compliance, $D(t)$, to relaxation modulus, E_r , of the asphalt mix. This information is then used to estimate thermal stress at any given depth and time in the AC layer. Stress intensity factor (K) and fracture parameters (A and n) determined from the creep compliance and AC material tests are used to estimate the growth of the thermal cracks in AC using the principles of fracture mechanics.

The Design Guide considers thermal strains at the surface of the AC layer and at a depth of 0.5 inches, as the top portion of the AC surface layer is more critically affected by thermal stresses. The following relationship is used to estimate the linear feet of thermal cracking in a 500-ft-long pavement section¹:

$$C_F = \beta_{T1} k_1 N (\log C \div h_{AC} \div \alpha)$$

where:

C_F = Amount of thermal cracking in linear ft per 500 ft

β_{T1} = Field calibration factor

k_1 = Regression coefficient for national calibration (353.47)

C = Crack depth, inch

h_{AC} = Thickness of AC layer, inch

α = Standard deviation of log of crack depths in the pavement

2.2.3 Permanent Deformation

Permanent deformation or rutting occurs in the wheel paths in the form of longitudinal depressions and develops as the number of load repetitions accumulate. Rutting can be classified as¹:

- Primary stage rutting has a high initial level of deformation primarily associated with volumetric change, with insignificant plastic (shear) deformations
- Secondary stage rutting is also associated with volumetric changes but at a much slower rate; shear deformations are increasing at an increased rate
- Tertiary stage rutting is associated with plastic (shear) deformation with insignificant volumetric changes

The 2002 Design Guide procedure for estimating rutting considers primary and secondary stage rutting; tertiary rutting is not considered. The procedure models secondary rutting and extrapolates the secondary rutting trend to estimate primary rutting. Rutting is estimated for the AC and granular materials for each subseason at the mid-depth of each sublayer in the pavement system. The permanent deformation for each sublayer for each subseason is added to estimate the total permanent deformation.

2.2.3.1 Permanent Deformation of AC Materials

The permanent deformation model for AC materials is based on statistical analysis of the data from the repeated load permanent deformation test. The AC permanent deformation model used in the 2002 Design Guide is¹:

$$\log (\epsilon_P \div \epsilon_R) = k_1 \beta_{R1} + k_2 \beta_{R2} \log T + k_3 \beta_{R3} \log N$$

where:

ϵ_P = Accumulated plastic strain after N load repetitions (in/in)

ϵ_R = Resilient strain of the AC mix (in/in) as a function of mix properties, temperature, and time rate of loading

T = Layer temperature (°F)

N = Number of load repetitions

The values of coefficients are:

$$k_1 = -3.15552, \quad k_2 = 1.734, \quad k_3 = 0.3993$$

$$\beta_{R1} = 1.4, \quad \beta_{R2} = 1.06, \quad \beta_{R3} = 1.05$$

The resilient strain at any depth along the vertical axis (defined in the x, y plane) can be determined using the three dimensional stress state and elastic properties (E and μ) of the AC material using the following equation:

$$\varepsilon_{RZ} = (1/E^*) (\sigma_Z - \mu \sigma_X - \mu \sigma_Y)$$

where:

ε_{RZ} = Vertical resilient strain

E^* = Complex modulus, determined using the master curve, as a function of mix properties, temperature, and time of loading

μ = Poisson's ratio

σ_Z = Vertical stress

σ_X, σ_Y = Stress in the perpendicular directions

Using calculated vertical resilient strain at any point in the AC layer and the permanent deformation equation, the plastic strain at any point in the AC layer (after N repetitions) can be determined.

2.2.3.2 Permanent Deformation of Granular Materials

The permanent deformation model for granular materials encompasses both base/subbase layers and the subgrade. The relationship implemented in the 2002 Design Guide is ¹:

$$\delta_a (N) = (\varepsilon_O \div \varepsilon_R) e^{-(\rho \div N)^\beta} \varepsilon_V h$$

where:

δ_a = Permanent deformation of the layer or sublayer

(N) = Number of load repetitions

$\varepsilon_O, \rho, \beta$ = Material properties

ε_R = Resilient strain imposed in the laboratory to obtain material properties

ε_V = Average vertical resilient strain in the layer or sublayer obtained from the response model

h = Thickness of the layer or sublayer

The ratio $\varepsilon_O/\varepsilon_R$ is determined separately for subgrade and granular materials using the following relationships:

Granular materials:

$$\log (\varepsilon_O/\varepsilon_R) = 0.80978 - 0.06626 W_C - 0.003077 \sigma_\theta + 0.000003 E_R$$

$$\log \beta = -0.9190 + 0.03105 W_C + 0.001806 \sigma_\theta - 0.0000015 E_R$$

$$\log \rho = -1.78667 + 1.45062 W_C + 0.0003784 \sigma_\theta^2 - 0.002074 W_C^2 \sigma_\theta - 0.0000105 E_R$$

Subgrade materials:

$$\log (\varepsilon_O/\varepsilon_R) = -1.69867 + 0.09121 W_C - 0.11921 \sigma_d + 0.91219 \log E_R$$

$$\log \beta = -0.9730 - 0.0000278 W_C^2 \sigma_d + 0.017165 \sigma_d - 0.0000338 W_C^2 \sigma_\theta$$

$$\log \rho = 11.009 + 0.000681 W_C^2 \sigma_d - 0.40260 \sigma_d + 0.0000545 W_C^2 \sigma_\theta$$

where:

W_C = Water content (%)

σ_d = Deviator stress (psi)

σ_θ = Bulk stress (psi)

E_R = Resilient modulus of the layer/sublayer

Using the ratio $\varepsilon_O/\varepsilon_R$ determined separately for granular and subgrade materials in the permanent deformation equations estimates the corresponding deformations after N number of load repetitions.

2.2.4 Estimating Pavement Smoothness (IRI)

The 2002 Design Guide procedure uses fatigue cracking, rutting, and thermal cracking to predict the smoothness of a flexible pavement structure at a given point in time. In addition, flexible pavement distresses such as potholes, longitudinal cracking, and block cracking also affect smoothness. The 2002 Design Guide procedure estimates smoothness as a function of base type, as indicated below. The designer has the option of directly considering potential of occurrence of distresses for which the ME performance models are not available.

2.2.4.1 Unbound Aggregate Base and Subbase

The smoothness prediction model of flexible pavements with unbound aggregate bases and subbases is¹:

$$\begin{aligned} \text{IRI} = & \text{IRI}_O + 0.0463 \text{ SF} (e^{(\text{age}-20)} - 1) + 0.00119 \text{ TC}_{LT} + 0.183 \text{ COV}_{RD} \\ & + 0.00384 \text{ FC}_T + 0.00736 \text{ BC}_T + 0.00155 \text{ LC}_{\text{SNWP}_{MH}} \end{aligned}$$

where:

IRI_O = Initial IRI

- SF = Site factor to account for soil movements and climatic factors
- $e^{(\text{age}+20)}-1$ = Age term
- TC_{L_T} = Length of transverse cracks
- COV_{RD} = Coefficient of variation of rut depth ($SD_{RD} \div RD$)
- SD_{RD} = Standard deviation of rut depth
- FC_T = Fatigue cracking in the wheel path
- BC_T = Area of block cracking as a percent of total lane area
- $LC_{SNWP_{MH}}$ = Length of sealed moderate and high severity longitudinal cracks outside the wheel path, ft/mile

The design guide procedure estimates mean rut depth (RD) using mechanistic principles which is then used to determine the rut depth standard deviation (SD_{RD}) using the following relationship:

$$SD_{RD} = 0.665 + 0.2126 RD$$

The site factor is determined using:

$$SF = 0.00005 R_{SD} PI (P_{.075} + 1) + 0.1 (\ln(FI + 1)) (P_{.02} + 1) (\ln(R_M + 1))$$

where:

- R_{SD} = Standard deviation of monthly rainfall, mm
- PI = Percent plasticity index of soil
- $P_{.075}$ = Percent passing the 0.075 mm sieve
- FI = Average annual freezing index
- $P_{.02}$ = Percent passing the 0.02 sieve
- R_M = Average annual rainfall, mm

2.2.4.2 Asphalt Treated Bases

The model used to estimate IRI of flexible pavements with asphalt treated bases is¹:

$$IRI = IRI_O + 0.0099947 \text{ Age} + 0.0005183 FI + 0.00235 FC_T + 18.36 (TC_{S_H})^{-1} + 0.9604 P_H$$

where:

- TC_{S_H} = High-severity transverse crack spacing, m
- P_H = High-severity patched area as a percentage of total area

2.2.4.3 Cement or Pozzolanic Treated Bases

The model used to estimate IRI of cement or pozzolanic treated bases and subbase is¹:

$$\begin{aligned} \text{IRI} = & \text{IRI}_O + 0.00732 \text{ FC}_T + 0.007647 \text{ SD}_{\text{RD}} + 0.0001449 \text{ TC}_{\text{LT}} \\ & + 0.00842 \text{ BC}_T + 0.0002115 \text{ LC}_{\text{NWP}_{\text{MH}}} \end{aligned}$$

where:

$\text{LC}_{\text{NWP}_{\text{MH}}}$ = Length of moderate and high longitudinal cracks outside
wheel path, m/km

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CHAPTER 3

FACTORIAL EXPERIMENT DESIGN

3.1 INTRODUCTION

The purpose of the calibration-validation process is to determine whether a conceptual model is a reasonable representation of the real-world, and if the desired correspondence (accuracy) exists between the model simulations and real-world conditions. The AC pavement performance indicators considered by the 2002 Design Guide include^{1,4}:

- Fatigue cracking
- Smoothness or ride quality
- Rutting or distortion
- Thermal cracking

The models to predict these performance indicators have been calibrated and validated using the Long Term Pavement Performance (LTPP) study test sections throughout North America under NCHRP Project 1-37A⁴. The national calibration-validation effort, however, cannot be expected to consider all potential factors that can occur in Mississippi. For example, factors such as maintenance strategies, construction specifications, aggregate and binder type, mixture design procedures, and material specifications can result in differences in performance. In fact, small differences in some of the above factors can cause large differences in performance¹.

3.2 FACTORIAL EXPERIMENT DESIGN

Within practical limitations of any experimental plan, it is impossible to account for or consider all potential factors in developing a national performance model. Therefore, a factorial experiment plan for Mississippi DOT must capture all potential factors, within practical limits, to identify potential differences between the national calibration factors and those applicable to Mississippi conditions and materials for long life AC pavements and overlays. The experimental plan must be geared towards determining what is causing

performance differences so that adjustments can be made to the national calibration functions. If significant differences are found between the predicted and measured performance indicators on Mississippi roadways, then it will be necessary to determine what factors are causing these differences so that adjustments can be made to the national calibration factors or functions. The performance indicators and factors affecting the performance indicators are discussed in the following sections.

3.2.1 Fatigue Cracking

Field studies for calibrating and validating the fatigue cracking model should not only focus on the classical concept of micro-fracture propagating from the bottom of the AC layer upwards to the surface, but should also explore the more recent concept of fatigue cracking that initiates at the surface and propagates downward. The fatigue cracking model is applicable to both bottom- and surface-initiated fatigue cracks. Because two types of fatigue cracking mechanisms are being considered, all field studies require the use of cores to document and determine the direction of crack propagation. Classical fatigue or “alligator cracking” starts at the bottom under the wheel load due to limiting tensile stresses being exceeded at the bottom of the AC layer. At the edge of the tire, the tension in the AC is at the top, hence a longitudinal crack appears.

Key factors that affect fatigue cracking and must be considered in the experiment design are discussed below.

- The temperature (environment) is a critical parameter for fatigue cracking since it influences the tensile strains and stresses present in the pavement, and impacts upon the specific multi-stiffness fatigue curve utilized in the analysis. Though the gulf and northern areas of the State have a slightly different climate, the State of Mississippi is considered to be one climate for all practical purposes.
- AC layer thickness not only influences strain and stress magnitude, but is directly linked to the location where fatigue cracks initiate (i.e., at the bottom of the AC layer or at the surface). Thus, total AC thickness is considered a key factor in the experiment. A comparable number of test sections will be required for both surface- and bottom- initiated fatigue cracks. Without the coring studies, only the total

magnitude of fatigue cracks can be calibrated—the individual failure mechanism cannot be confirmed.

- Pavement type and rehabilitation strategy are additional factors of the experiment for checking the key failure hypothesis and to determine whether there is any bias for the different pavement structures or calculation methodologies. The pavement types and rehabilitation strategies that are commonly used in Mississippi should be considered key factors within the experiment.
- The resilient modulus of the subgrade soil is not believed to be a critical factor related to the occurrence of fatigue cracks. However, most of the experimental designs in the LTPP program include the type of subgrade soil. Subgrade soil type and whether the soil is expansive should be included as factors; however, Mississippi stabilizes almost all subgrades before construction, hence, stabilized or unstabilized subgrades are considered in the experiment design.
- Mix stiffness and dynamic modulus has been found to be important parameters for fatigue cracking in that they are primary factors influencing the traditional tensile strain-fatigue cycle distress curves (cracks initiating at the bottom of the layer and propagating to the surface). The dynamic modulus is dependent on (or is a function of) temperature and age, among other mixture properties, and is considered a covariate parameter in the experiment. For surface-initiated fatigue cracks, other material properties may need to be included as key factors.

It is intuitively obvious that the model must represent a range of fatigue cracking that covers the normal range found along roadways. If an adequate range of cracking extent or magnitude is not included, the accuracy of the model over a wide range will be questionable. Field sections with varying levels and types (surface-initiated versus bottom-initiated) of fatigue cracks should be included in the experimental plan to cover the range of conditions. However, as long as sufficient time-series distress data are available for each test section, the range in fatigue cracking need not be included as a key factor in the experiment. Fatigue cracking magnitude will be used in selecting the test sections for the individual cells. Where possible, two test sections will be selected for each cell—one with a low amount of fatigue

cracking and the second or companion test section with a high amount of cracking. This will allow the user to check for any bias in the differences as a function of cracking amounts.

3.2.2 Thermal Cracking

The field studies for the thermal cracking model should investigate how materials and structural factors affect the initiation and propagation of thermal cracks in pavements, and the relative importance of single, large excursions in temperature compared to many smaller temperature cycles as primary determinants of their frequency and extent. Thermal cracking of AC mixtures is related to two major parameters: the asphalt mixture stiffness (or binder type/grade) and strength, and the magnitude and duration of cold temperatures (i.e., the environment in which the pavement is placed). The following factors were considered within the experiment:

- The type or stiffness of the asphalt binder (with and without modification) and mix type will be used as surrogates for mix stiffness
- The environment or duration and magnitude of cold temperatures throughout the pavement structure
- The distress magnitude (expressed either in terms of absolute crack spacing or as a ratio of the length of thermal cracks per section to the total section length) is also a key factor; time-series cracking data can be used to obtain the different magnitudes of thermal cracking, so that different magnitudes are not needed in different cells
- The total AC layer thickness should also be included in the experimental design because the present Superpave thermal cracking prediction model does not count a thermal crack until it propagates through the entire thickness of the AC layer

3.2.3 Ride Quality or Smoothness

Ride quality or smoothness is one of the more common performance indicators used by State DOTs for both design and pavement management purposes. One key concept included in the 2002 Design Guide is that there is a defined relationship between distress and smoothness. In other words, certain distresses have a significant effect on the IRI measured over time. Thus, smoothness is considered a key element or parameter in the experiment. Five models or equations are included in the 2002 Design Guide—three for new construction

(conventional AC pavements, deep-strength AC pavements, and semi-rigid AC pavements) and two for AC overlays (AC overlays of AC pavements and AC overlays of portland cement concrete [PCC] pavements). The semi-rigid and deep strength AC pavements are not constructed in Mississippi and hence are not considered in the experiment design. Thus, only three models will be evaluated by the experiment.

3.2.4 Rutting

The field studies for rutting should consider both volumetric rutting (i.e., a predominantly linear relationship between the logarithm of the plastic strain and that of the number of load cycles) and the critically important behavior associated with tertiary flow (or plastic flow) of AC mixtures. The mechanistic procedure will be used to predict rutting in each layer of the pavement structure, including the subgrade. Thus, it is necessary to know the actual permanent deformation that has occurred in each layer of a specific test section. This would require the use of trenches to measure the rutting in each layer and within the subgrade.

Five critical factors are necessary for the experimental design for calibration of the rutting-permanent deformation model. Each factor is discussed below, along with some additional considerations that will be used in the site selection process.

- The pavement temperature regime (environmental zone) is a major consideration for permanent deformation in AC mixtures because it influences the viscoplastic properties of the mixtures. As discussed earlier, the State of Mississippi is considered one climatic zone.
- AC layer thickness, insofar as it influences the magnitudes of stress and strain in the underlying layers, also has relevance to the development of rutting. Thus, it is considered a key factor in the experiment. As stated above, trenches are required to measure the permanent deformation in each layer. Without these trenches, only the total magnitude of rutting measured at the surface can be calibrated.
- Pavement type and rehabilitation strategy are additional factors of the experiment for checking the failure hypothesis and to determine if there are any biases for the different pavement structures or calculation methodologies. The pavement types and

rehabilitation strategies that are commonly used in Mississippi should be considered key factors within the experiment.

- Asphalt with and without modification is included as a factor in the experiment, because of the importance of asphalt stiffness in term of rutting.
- Although permanent deformation of AC mixtures is a complex phenomenon, mix stiffness or the dynamic modulus is considered a first-order indicator of its susceptibility to this distress. This arises from the fact that the ratio of plastic to resilient strains generally obeys a power law related to the number of repetitions. In general, different binder or performance grades of asphalt with different gradations (coarse to fine gradations) can be included in the selection of test sections for specific cells to cover the range of stiffness. In addition, as stated above for fatigue cracking, the dynamic modulus is dependent on temperature and age.
- Similar to fatigue cracking, the rut depths measured at the surface should cover the normal range found in pavements. It is expected that time-series rutting data can be used to cover the range in rut depths, so separate cells are not needed.
- Similar to the fatigue cracking factorial, two test sections will be selected for each cell—one with low rut depths and the second with relatively higher rut depths.

3.2.5 Levels of Factors Affecting Performance

Table 3.1 shows important factors for each of the flexible pavement performance indicators that must be included in the factorial experiment design. The levels for these factors are established based on the previous discussion and in consultation with the Research, Roadway Design, and Materials Divisions of Mississippi DOT during a meeting held on February 4, 2003. Traffic is not included in the factorial experiment design because it is assumed to be indirectly related to AC layer thickness. Figure 3.1 shows the factorial experiment design.

Table 3.1. Factors affecting flexible pavement performance and experiment design levels.

AC pavement performance factors and levels			Pavement performance indicators			
			Cracking		Ride quality	Rutting
Factors	Levels	Description	Fatigue	Thermal		
Temperature	1	One climatic zone	X	X		X
AC thickness	3	Low (<6"), medium (6"-9"), high (>9")	X	X	X	X
Base / subbase	-	Cement and asphalt treated	X		X	
Subgrade soil	2	Stabilized, unstabilized	X		X	
Pavement type	6	Conventional, semi rigid, deep strength, AC overlays of AC and PCC pavements	X		X	X
Binder type	2	Conventional, modified	X	X		X
Mix type	2	Dense, Superpave	X	X		X

3.3 TEST SECTIONS FOR THE FACTORIAL EXPERIMENT DESIGN

Figure 3.1 shows the experimental factorial that was developed to accomplish calibration-validation of national models for Mississippi.

Subgrade Type	Binder Type	Mix Type	Pavement Type											
			Conventional ¹			Semi Rigid ²			Deep Strength ³			AC overlay over		
			AC Thickness											
			L	M	H	L	M	H	L	M	H	AC	JCP	CRCP
Non Stabilized	Modified	D ⁴												
		S ⁴												
	PG	D												
		S												
Stabilized	Modified	D												
		S												
	PG	S												
		D												

Notes: ¹ Flexible pavements with thick unbound base/subbase layers

² AC pavements with cement- or lime-treated base/subbase layers

³ AC pavements with asphalt treated base/subbase layers

⁴ D: Dense HMA mix, S: Superpave HMA mix

Figure 3.1. Factorial experiment design for calibration validation of performance models.

There may be a need to select two sets of test sections: one set for fatigue cracking and ride quality, and the second set for rutting and thermal cracking. The two sets are needed because foundation or supporting layers are related to fatigue cracking and ride quality, and asphalt type or stiffness are more related to rutting and thermal cracking. It is expected that each site can be used for both experiments to limit the number of test sections required to accomplish the experimental objectives. Two test sections within each cell are planned whenever possible. These two test sections will have different performance measures but be about the same age, if at all possible.

The LTPP test sections located in Mississippi should be used as the first priority sites, because of the amount of time-series performance, materials, traffic, and other data that have been collected and are readily available for these test sections. Test sections from Mississippi DOT's pavement management system (PMS) can be used to fill in the gaps. To supplement the LTPP sites and Mississippi DOT tests sections, LTPP sites in the adjoining States can be reviewed for consideration for use in Mississippi's experimental plan and factorials.

3.3.1 Test Sections from the LTPP Program

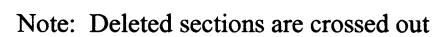
The LTPP⁵ program monitors more than 2,400 AC and PCC test sections designated as general pavement studies (GPS)⁶ and specific pavement studies (SPS)⁷ test sections. Table 3.2 describes these sections and indicates the experiments that are applicable to this study and the number of available records. GPS experiments 1, 2, 6, and 7 are applicable to this research; there are no GPS-1 test sections in the State. SPS experiments 5 and 6 are directly related to this research; however, some useful performance information may be obtained by reviewing data for experiment SPS-3. Figure 3.2 shows the approximate location of GPS and SPS LTPP test sections in Mississippi, and Table 3.3 is a listing these test sections.

The selected test sections for the three pavement types and their AC overlays are shown in Table 3.4 and discussed in the following sections. The latest version of the LTPP database was the source of information shown in Table 3.2 and Table 3.4^{8,9}.

Table 3.2. GPS and SPS test sections in Mississippi.

Number	Description	Test Sections	Records
<i>General Pavement Studies (GPS)</i>			
GPS-1	AC on Granular Base	0	0
GPS-2	AC on Bound Base	14	14
GPS-3	Jointed Plain Concrete Pavement (JPCP)	2	2
GPS-4	Jointed Reinforced Concrete Pavement (JRCP)	1	1
GPS-5	Continuously Reinforced Concrete Pavement (CRCP)	5	6
GPS-6	AC Overlay of AC Pavement	7	7
GPS-7	AC Overlay of PCC	3	3
GPS-8	Not used	--	--
GPS-9	Unbonded PCC Overlays on PCC Pavements	2	2
Total for GPS Experiments		34	35
<i>Specific Pavement Studies (SPS)</i>			
SPS-1	Strategic study of structural factors for flexible pavements	0	0
SPS-2	Strategic study of structural factors for rigid pavements	0	0
SPS-3	Preventive maintenance effectiveness of flexible pavements	5	10
SPS-4	Preventive maintenance effectiveness of rigid pavements	3	4
SPS-5	Rehabilitation of AC pavements	10	18
SPS-6	Rehabilitation of jointed PCC pavements	0	0
SPS-7	Bonded PCC overlays on concrete pavements	0	0
SPS-8	Study of environmental effects in the absence of heavy loads	3	3
SPS-9	Validation of Superpave asphalt specification and mix design	3	5
Total for SPS Experiments		24	40

Note: Sections applicable to this research study are highlighted.



3-10

Table 3.3. Location and status of Mississippi LTPP GPS and SPS test section^{11, 12}.

SHRP ID	Highway	County	Direction	Status
<i>General Pavement Studies Test Sections</i>				
28-1001	US-45	Lee	NB	
28-1016	MS-35	Attala	NB	Out of Study 10/97
28-1802	US-84	Covington	EB	
28-2807	MS-6	Lafayette	EB	Out of Study 8/99
28-3018	US-72	Tishomingo	WB	
28-3019	US-72	Tishomingo	WB	
28-3081	US-78	Itawamba	WB	
28-3082	US-82	Montgomery	WB	
28-3083	MS-310	Marshall	EB	
28-3085	MS-310	Marshall	EB	
28-3087	MS-7	Lafayette	SB	
28-3089	MS-6	Lafayette	EB	Out of Study 8/99
28-3090	MS-315	Panola	EB	
28-3091	US-45	Lauderdale	SB	
28-3093	I-10	Jackson	EB	
28-3094	I-10	Jackson	EB	
28-3097	I-55	De Soto	NB	Out of Study 10/94
28-3099	I-20	Scott	EB	Out of Study 8/99
28-4024	MS-1	Washington	NB	
28-5006	US-78	Lee	WB	
28-5025	US-84	Lincoln	WB	
28-5803	US-78	Marshall	WB	
28-5805	I-10	Harrison	WB	Out of Study 2/99
28-7012	I-20	Warren	WB	
28-9030	I-20	Warren	EB	
<i>Specific Pavement Studies Test Sections</i>				
28A3xx	US-82		EB	Out of Study 08/18/99
28A4xx	MS-1		NB	Out of Study 08/18/99
2805xx	I-55		NB	Out of Study 08/18/99
2808A4xx	MS-315		NB	Constructed 10/2/96
2809xx	I-55		SB	Constructed 8/95 (Overlay)

Table 3.4. Test sections selected from the Mississippi LTPP sections.

Sub-grade	Binder	Mix type	AC thickness			AC overlays of				
						AC (surface preparation)			JCP ⁶	CRCP ⁷
			< 6''	6'' – 9''	> 9''	Yes	No	Recycled		
Conventional Pavements ¹										
Stabilized	PG	D								
		S								
	Mod	D								
		S								
Non Stabilized	PG	D	A310-1, A320-1, A330-1, A350-1				A310-2, A320-2, A350-2		7012-1	
		S								
	Mod	D								
		S								
Semi Rigid Pavements ²										
Stabilized	PG	D			3094-1		3094-2		3097-1	3099-2
		S								
	Mod	D								
		S								
Non Stabilized	PG	D	3083-1, 3090-1, 3085-1	3081-1, 3087-1	3089-1, 2807-1	3081-2, 3087-2, 2807-2				
		S								
	Mod	D								
		S								
Deep Strength Pavements ³										
Stabilized	PG	D	3093-1	3082-1*			3093-2, 0504-2, 0505-2			
		S		*cement treated SG		0506-2, through 0509-2	0501-1 through 0509-1	0502-2, 0503-2		
	Mod	D								
		S								
Non Stabilized	PG	D	1802-1, 3091-1, 1016-1, 1001-1			3091-2, 1002-2				
		S								
	Mod	D								
		S								

Notes: ¹ Flexible pavements with thick unbound base/subbase layers

² AC pavements with cement- or lime-treated base/subbase layers

³ AC pavements with asphalt treated base/subbase layers

⁴ SPS-3 sections (A3XX-X) have limited inventory information available

⁵ SPS-5 sections (050X-X) have limited inventory information available

⁶ Jointed concrete pavement

⁷ Continuously reinforced concrete pavement

3.3.2 Test Sections from Mississippi DOT Pavement Management System

A number of cells in the factorial experiment design shown in Table 3.4 are blank, as all the required test sections could not be filled using the LTPP database. The Mississippi DOT is currently working to obtain additional test sections from their pavement management database. The list of test sections was not available at the time of writing this document; however, it will be available at the start of Phase II research.

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CHAPTER 4

CALIBRATION TO LOCAL CONDITIONS

4.1 NEED FOR CALIBRATION

The ME-based 2002 Design Guide procedure will develop more reliable and cost-effective designs but its application is also comparatively complex. Performance models based on mechanistic principles require a comprehensive set of input data, including improved traffic and materials characterization. A significant effort will be required to evaluate and tailor the procedure for the Mississippi DOT.

The 1962 AASHTO design procedure and its several updates required many years of dedicated implementation efforts by state DOTs that focused on obtaining appropriate inputs, developing regional climatic factors, setting up subgrade strength correlations, etc. In addition to these, many DOTs set up their own mini test road programs to further calibrate to local conditions. It is anticipated that the 2002 Design Guide procedure will require a similar, if not more dedicated, effort for successful implementation.

An ME design approach involves relating computed engineering response parameters, such as stresses and/or strains, to pavement performance. The *mechanistic* aspect of the design method has as its basis an analytical model that uses principles of mechanics of materials and continuum mechanics. The purpose of the analytical response model is to predict pavement response to applied traffic loads. The *empirical* component relates the outputs from the mechanistic model to observed pavement performance. Uncertainties in environmental conditions, construction quality, and maintenance strategies complicate prediction of pavement performance. Transfer functions or performance models are used to relate mechanistic responses to performance parameters.

Actual distress mechanisms are far more complex than can be predicted reliably using the performance models. Hence, the performance models are calibrated using real-world performance data to obtain realistic performance prediction. The flexible pavement distress

models shown earlier have been calibrated at the national level using data from the LTPP program. As such, the current design procedure is biased towards national averages. About 80 percent of the data was used for calibration and the remaining 20 percent of the data was used for validation of the calibrated models. Because of reasonable results from validation tests, all the data were combined to further improve the performance models. The final calibrated national models are not necessarily accurate for all conditions and regions of the country, prompting the need for a more local or state-level calibration and validation¹.

4.2 CALIBRATION APPROACH

The 2002 Design Guide development team have successfully completed the national calibration and validation process. However, the team recommends further calibration and validation as a prudent step in implementing the new design procedure. An approach for local calibration and validation was thus recommended as part of the 2002 Design Guide. This approach is adapted for implementing the 2002 Design Guide for the Mississippi DOT, after making modifications to better suit Mississippi DOT needs. The modified calibration process includes the following tasks¹:

1. Input data review
2. Sensitivity analysis
3. Comparative studies
4. Performance model evaluation
5. Local calibration and validation
6. Modification of default inputs and calibration coefficients
7. Final sensitivity analysis and comparative studies

4.2.1 Input Data Review

All the required inputs will be reviewed. Relative to the current Mississippi DOT design procedure, some of the inputs will remain the same, others will be totally new, and some might be defined differently.

The 2002 Design Guide uses a hierarchical approach to all the input data; data are classified as Level 1, 2, or 3 depending upon the importance of the project. For example, low-level roads may use Level 3 data, whereas high-volume roads would use Level 1 data

because a more precise design is required. This approach provides the designer with more flexibility in obtaining the design inputs based on the criticality of the project and available resources. For a given design project, inputs from a mix of levels may be used; no matter what input levels are used, the computational algorithm for damage in the design procedure remains the same.

Level 1 data have the lowest level of error and provide for the highest level of accuracy and reliability. Level 1 data are used to design high-volume roads where there are dire safety or economic consequences of early failure. Obtaining Level 1 inputs requires more resources and time than other levels, as Level 1 uses site-specific data such as laboratory test data on soils or materials. Another example would be Falling Weight Deflectometer (FWD) testing and backcalculation of pavement characteristics for a rehabilitation project or site-specific weigh-in-motion (WIM) traffic data.

Level 2 data generally represent the accuracy of inputs used in the current State DOT design procedures. Level 2 data provide an intermediate level of accuracy and are used when resources or testing equipment are not available for tests required for Level 1. These are usually user-selected inputs selected from experience or from a database of earlier test results. These could also be estimated through correlations with simpler tests. Examples of such data include estimating asphalt concrete dynamic modulus from binder, aggregate, and mix properties, or using site-specific traffic volume and traffic classification data in conjunction with agency-specific axle load spectra.

Level 3 inputs are used where there are minimal consequences of early failure (e.g., lower volume roads) and have the lowest level of accuracy. These are usually user-selected default values and represent typical averages for a particular part of the state.

The objective of this task is to familiarize the Mississippi DOT personnel with the inputs required for the new design procedure. This would also include the following activities for the DOT:

- Assessment of how best to obtain an input
- Estimation of significance of input in Mississippi
- Determination of appropriate levels for use in design
- Appropriate default values for inputs and ranges (Level 3)

- Performance criteria for design of various highway classification
- Reliability of design levels

4.2.2 Sensitivity Analysis

This task is a typical sensitivity analysis in which the same problem is run multiple times while changing the value of a particular variable to determine its effect on the final answer. For the purposes of sensitivity analysis, typical DOT pavement designs for high-, medium-, and low-volume highways would be selected with all the design inputs. The 2002 Design Guide software will be executed several times while varying the values of a particular input variable to determine its effect on predicted distresses and IRI. The results are evaluated to categorize the inputs as having a significant, moderate, or only minor effect on one or more of the outputs.

4.2.3 Comparative Studies

A number of comparative studies will need to be conducted between the 2002 Design Guide procedure and the existing DOT procedure. These studies would compare the results of typical low-, medium-, and high-volume highway designs using both procedures. It is beneficial to use existing projects that have been constructed for this comparison. The results will be evaluated and will be discussed with DOT designers so as to determine if these designs are adequate for Mississippi highways. If the pavement sections from the 2002 Design Guide are under- or over-designed, then the reasons for this are documented if possible.

4.2.4 Performance Model Evaluation

The 2002 Design Guide Procedure will be evaluated to determine if the national models and calibration factors are adequate for the construction practices, materials, climate, and traffic prevalent in Mississippi. Based on the results of the comparative studies, the nationally calibrated models could be evaluated to determine if they provide a reasonable answer for Mississippi conditions. The objective will be achieved by using existing Mississippi highway pavements with performance history and compare actual field distresses and IRI to those predicted by the 2002 Design Guide procedure.

4.2.5 Local Calibration and Validation

None of the Mississippi LTPP test sections were used in the national calibration effort, and there is a high probability that adjustments to the calibration factors will need to be made before using the 2002 Design Guide procedure for designing pavements in Mississippi. The calibration-validation of performance models for local conditions will require at least the following tasks:

- Selection of sufficient number of representative pavement test sections
- Establishing a database with appropriate design, materials, construction, traffic, and performance data
- Developing input guidelines for available data
- Confirming if significant differences exist between predicted and observed distresses
- Modifying the calibration factors, if needed
- Validating local calibration

Details on how to accomplish these tasks are provided in Chapter 6, “PHASE II Implementation Work Plan and Budget”

4.2.6 Modification of Default Inputs and Calibration Factors

If significant differences are found between predicted and observed distresses and IRI during earlier evaluations, the default inputs and calibration factors in the 2002 Design Guide software will need to be updated. The calibration process will also establish the level of accuracy required for key inputs and default input values. These results will be used to develop new standard deviations for all inputs. The new model, calibrated for local conditions, improves the design reliability (less cost), as there is less uncertainty or error associated with the design.

4.3 CALIBRATION-VALIDATION PROCEDURE

The calibration-validation process determines if a conceptual model is a reasonable representation of the real-world, and if there is desired level of accuracy or correspondence between the model simulations and real-world conditions. The success of this process can be gaged on the biases in predicted values and the standard error of estimate, S_e (see Figure 4.1). The S_e for the validation may not be equal to the S_e for calibration; generally, it is higher. To

test if it is significantly higher, which would suggest that the validation failed, a chi-square test will be used. Conversely, an operational definition of “reasonable correlation” is that the null hypothesis is accepted when the student and/or paired t-tests are used to compare the observed and predicted responses at a confidence interval of 95 percent ($\alpha = 0.05$).

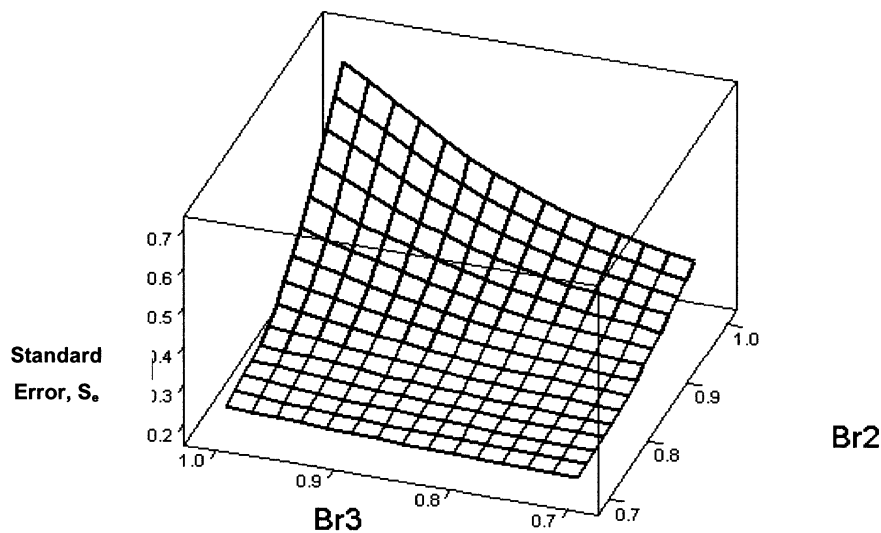


Figure 4.1. The least standard error of estimate defines the final calibration coefficients.

If the validation process results in the rejection of the null hypothesis at the chosen significance level, the soundness and completeness of the conceptual and the operational models must be re-evaluated. Further model changes will require another round of verification, calibration, and validation to assure accuracy of the revised models.

4.4 DATA REQUIREMENTS

The data requirements for local calibration-validation are dictated by the input requirements of the 2002 Design Guide procedure. The test sections should represent a wide range of pavement conditions. Periodic performance data should be available in terms of distresses collected at periodic intervals. Traffic, climate, materials and distress data will be needed for each test section; these are summarized in Table 4.1.

Table 4.1. Summary of Data needed for calibration and validation of models.

Data Category	Action Item	Mississippi DOT Resources Needed
Visual Condition Data	<ul style="list-style-type: none"> For test sections included in Phase II research, collect project information relevant to design, e.g., site and design factors Tabulate performance history of existing pavement sections in terms of distresses considered in the 2002 Design Guide approach Flexible pavements: fatigue cracking, permanent deformation, thermal cracking, smoothness, etc. Rigid pavements: fatigue cracking, joint faulting, smoothness, etc. 	<ul style="list-style-type: none"> Staff time to help conduct records review Staff time to retrieve information from PMS data base
Field Destructive Testing	<ul style="list-style-type: none"> Conduct coring on a limited number of sections to confirm the development of fatigue cracking (flexible and rigid) and rutting (flexible) Conduct coring for retrieval of field samples for laboratory evaluation of materials properties 	<ul style="list-style-type: none"> Traffic control and equipment to perform coring and boring
Laboratory Testing	<ul style="list-style-type: none"> Select representative number of HMA mixes, subgrade soils, unbound materials Perform laboratory testing of retrieved project materials to include dynamic modulus of HMA, resilient moduli of unbound materials, and elastic moduli of cement treated materials. Perform creep compliance and coefficient of thermal expansion testing for select materials (for climatic model) 	<ul style="list-style-type: none"> HMA/subgrade information from existing MsDOT study Materials Division to provide testing support. ERES will provide direct assistance on detailed testing procedures
	<ul style="list-style-type: none"> Select representative number of concrete mixes, subgrade soils, unbound materials Perform laboratory testing to measure desired strength and stiffness properties of PCC materials Perform ultimate shrinkage and coefficient of thermal expansion testing (for climatic model) 	<ul style="list-style-type: none"> Materials Division to provide testing support ERES will provide direct assistance on detailed testing procedures
FWD Testing and Processing	<ul style="list-style-type: none"> Perform FWD testing needed to determine in-place material properties for use in validating rehabilitation design if previous data are not available Only limited number of sections will be tested as per experiment design 	<ul style="list-style-type: none"> 9-12 days of FWD testing on select projects Traffic control
Ride Quality Assessment	<ul style="list-style-type: none"> From LTPP and MsDOT PMS data bases Construction records 	<ul style="list-style-type: none"> Staff time to help conduct records review
Traffic Data	<ul style="list-style-type: none"> Default traffic inputs based on functional class and other factors 	<ul style="list-style-type: none"> Available from existing MsDOT research study

Additional details about traffic, climate, materials, and pavement distress data items are provided in the following sections.

4.4.1 Traffic

Knowledge of cumulative traffic loads over the entire pavement lifespan is crucial for the pavement analysis process. The 2002 Design Guide needs traffic input in terms of *load spectra*; hence, traffic loads need to be estimated in terms of *load spectra*. *Load spectrum* is defined as distribution of the number of axles by load ranges for different axle configurations (single, tandem, tridem)¹³. Typical data required would include^{1,13,14}:

- Base year truck-traffic volume
- Vehicle (truck) operational speed
- Truck-traffic directional and lane distribution
- Truck type and axle load distribution
- Axle and wheel base configurations
- Tire characteristics and inflation pressure
- Truck lateral distribution
- Truck growth factors

Table 4.2 shows typical traffic data that would be needed for calibration and validation of performance models.

Table 4.2. Typical traffic data required for various input levels.

Data Element		Input Levels			
		Level 1	Level 2	Level 3A	Level 3B
Traffic Load/Volume Data	WIM data – site/segment specific	X			
	WIM data – regional weight summaries		X	X	
	AVC data – site/segment specific	X	X		
	AVC data – regional truck volume summaries			X	
	Vehicle counts – site specific			X	X

Mississippi DOT research study SS 165¹⁵ should be able to provide a lot of this information, such as the following:

- Traffic volume adjustment factors
 - Monthly adjustment factors

- Percent of a given truck class in a month
- Vehicle class distribution factors
- Hourly truck distribution factors
- Traffic growth factors
- Axle load distribution factors
 - Single, tandem, tridem, quad
 - Vehicle classes 4 through 13
 - % within each axle type and vehicle class

4.4.2 Climate

Historical temperature and rainfall data from the nearest weather station will suffice for the purposes of this research. The 2002 Design Guide software includes an enhanced climatic model that will be used to further determine various climatic inputs^{1,16}.

4.4.3 Materials

The pavement material properties used by the 2002 Design Guide to predict stress, strain, and displacement are elastic modulus (E) and Poisson's Ratio (μ). These are mandatory inputs for all levels of design¹. The 2002 Design Guide divides pavement materials into the following six categories^{1,17}:

- AC materials
- PCC materials
- Cement stabilized materials
- Unbound granular materials
- Subgrade soils
- Bedrock

Table 4.3 lists the material characterization data for various levels of inputs for new construction and rehabilitation. The data from different levels could be combined for the purposes on calibration and validation.

Table 4.3. Material data for various input levels.

Material Category	New / Rehab ?	Input Levels		
		Level 1	Level 2	Level 3
Asphalt Concrete	New	E* from the complex modulus test, binder test data, simulated mix aging data, develop mix master curve	Predict E* using equation, binder test data, develop mix master curve	Predict E* using equation, develop mix master curve
	Rehab	FWD backcalculation, lab testing of cores, develop mix master curve with aging	Mix properties from cores, develop mix master curve	Mix master curves from typical mix properties
Portland Cement Concrete	New	E _C from compressive modulus test at 7, 14, 28, and 90 days	E _C estimated from the compressive strength	Typical values based on DOT experience
	Rehab	FWD backcalculation or coring and lab testing		
Cement Stabilized	New	Lower strength materials – unconfined compressive strength test High strength materials – modulus of rupture		Typical values based on DOT experience
	Rehab	Backcalculated values from FWD testing adjusted using distress survey data	Backcalculated values from FWD testing adjusted using probable distress progression over time	
Unbound Granular	New	Direct M _R test or M _R predictive equations from k _i parameters	Correlate M _R from lab or empirical data, from predictive equations	Soil classification correlations
	Rehab	Backcalculated MR, direct FWD results and typical backcalculated values		
Subgrade	New	Direct M _R test or M _R predictive equations from k _i parameters	Correlate M _R from lab or empirical data, from predictive equations	Soil classification correlations
	Rehab	Backcalculated MR, direct FWD results and typical backcalculated values		
Bedrock (if within 15 ft)	Solid	Typical range: 750 – 2,000 ksi, typical value: 1,000 ksi		
	Fractured	Typical range: 250 – 1,000 ksi, typical value: 500 ksi		

4.4.4 Pavement Distress Data

Pavement distress data from the LTPP data base and the Mississippi DOT PMS data base will be used for calibration and validation of performance models. Information would be needed about the following:

- Fatigue cracking (bottom up and top down)
- Smoothness or ride quality
- Rutting or distortion
- Thermal cracking

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CHAPTER 5

TECHNOLOGY TRANSFER AND TRAINING

5.1 INTRODUCTION

Training and communications are essential for smooth implementation of the 2002 Design Guide in Mississippi. The 2002 Design Guide team is developing a number of implementation products that could be used to help Mississippi DOT personnel become more familiar with the new design procedure. This comprehensive package of materials to increase awareness of the 2002 Design Guide includes:

- Guide text and appendices
- User's manual in support of the software
- Training course on software execution
- Laboratory and field test procedures to determine inputs
- Management video

Training materials will be developed in Phase II to help the Mississippi DOT get acquainted with the new design procedure.

5.2 TECHNOLOGY TRANSFER PROTOCOLS

Training of Mississippi DOT personnel will be an integral part of the overall 2002 Design Guide implementation program (during Phase II). To address the potential training needs initially, ERES has developed a list of the necessary training materials, which includes:

- Training courses and seminars
- Self-learning tools (videotapes and CDs)
- Pavement design manuals
- User's manual for software

The list of training materials will be structured to address needs at all levels, both within and outside the DOT. The list will include training materials for high-level managers,

engineers, and field/laboratory technical personnel located within in the DOT and within supporting consultant, material supplier, and contractor organizations.

These technology transfer protocols are described briefly in the following sections.

5.2.1 Training Courses and Seminars

The 2002 Design Guide incorporates many new concepts dealing with mechanistic principles. NHI training course 131064, “Introduction to Mechanistic Empirical Pavement Design Procedures,” is usually recommended as a good introduction to ME design concepts. The Mississippi DOT has been proactive in this regard, having already conducted this course on its premises.

The next step would be to adapt the 2002 Design Guide training manual for use by the Mississippi DOT. This training manual will be enhanced by adding additional introductory material for those with inadequate experience or who have not had the NHI course. The training course would cover the 2002 Design Guide procedure in detail, including all inputs and the design procedure for new construction and rehabilitation of existing pavements.

A training course could also be developed to provide Mississippi DOT personnel with hands-on experience using the Design Guide software. This training course would include software updates specific to Mississippi needs, such as locally attuned performance models and default input values.

In addition, a special set of brochures and visual aids could be developed to introduce the design procedure to industry, local governments, and consulting personnel. All these have a stake in successful implementation of the Design Guide in Mississippi.

Depending on the needs of the target audience, the training seminars could be held at a central location or at various Mississippi DOT districts.

5.2.2 Self-Learning Videotapes and CDs

Self-learning videotapes and CDs are great tools for people to familiarize themselves with the 2002 Design Guide at their own pace. An introductory CD could be developed for upper level managers and administrators to familiarize them with the 2002 Design Guide. These videotapes/CDs would include information about the basic elements of the 2002

Design Guide, including a walkthrough of a typical new construction and rehabilitation design. Information from basic inputs to final results would be reviewed.

Self-learning videos and CDs usually supplement the training courses and essentially contain all the information presented during the training course.

5.2.3 Pavement Design Manual

The pavement design manual prepared as part of the 2002 Design Guide project will need to be updated to incorporate all the Mississippi-specific changes. This manual will explain the design procedure for new and rehabilitation designs and describe all aspects from inputs to analysis of the outputs.

5.2.4 User's Manual for the Software

The 2002 Design Guide software manual will be updated as part of the overall implementation project. Changes made in the procedure to accommodate Mississippi-specific needs will be included. The user manual will be used with the training course on the Design Guide software and for future reference.

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CHAPTER 6

PHASE II IMPLEMENTATION WORK PLAN AND BUDGET

6.1 IMPLEMENT THE ROAD MAP

Mississippi DOT is planning an implementation process for the 2002 Design Guide to ensure that all of the input procedures are acceptable and practical and that the distress and smoothness prediction models represent pavement performance in Mississippi. The implementation of the 2002 Design Guide for Mississippi is being conducted in two phases. This report summarizes the Phase I research and provides a plan for Phase II. A brief synopsis of these two phases is provided below:

- Phase I (current research) included general familiarization of Mississippi DOT staff with the 2002 Design Guide, discussions and meetings to establish the scope of pavement types and rehabilitations of interest to the Mississippi DOT, development of a factorial experiment design, recommendation of test sections for calibration and validation of the performance models, and preparation of a detailed plan for Phase II implementation. Only flexible pavements were considered in Phase I.
- Under Phase II (future research), the research team would conduct a detailed review of all design inputs, an initial sensitivity analysis and comparison with current Mississippi DOT procedures, and provide guidance to carry out the required field and laboratory testing. Phase II will include obtaining all remaining design inputs (e.g., obtaining detailed traffic inputs, selection of performance criteria, material testing), establishment of default inputs where applicable, calibration and validation of the distress prediction models with Mississippi pavement performance data, additional sensitivity analysis and a final comparison of 2002 Design Guide with current Mississippi DOT design procedure results, preparation of detailed design and training manuals for use by designers, customization of software, and additional training of staff.

Phase I research was summarized in earlier chapters; Phase II details are provided here.

6.2 IMPLEMENTATION WORK PLAN

Full implementation of the 2002 Design Guide under Phase II will include the following tasks.

6.2.1 Review Inputs Required for the 2002 Design Guide

Under this task, ERES will review the 2002 Design Guide inputs for new and rehabilitation design and compare them to the inputs used in the current Mississippi DOT design procedure. The input review will include obtaining feedback from Mississippi DOT for each input on (a) how to best obtain the input, (b) estimated significance of input in Mississippi, (c) appropriate levels for use in design (Level 1, 2, or 3), (d) appropriate default and ranges for Level 3 (tentative values), (e) design performance criteria for Interstate and off-interstate highways, (f) reliability level for design, and (g) other topics as identified.

This task will also recommend the precision needed for each design input variable and will outline the circumstances for using Level 1, 2, or 3 designs. This will also identify specific problems in obtaining proper input data and potential solutions of these problems and will confirm defaults for all input values used in Level 3 and acceptable ranges for all inputs.

6.2.2 Conduct Preliminary Sensitivity Analysis

Under this task, ERES will conduct a limited sensitivity analysis of the Design Guide software. This analysis will include different ranges of inputs, design features, traffic loading, environmental zones, subgrade types, and other variables required by the design procedure. Comparisons of the 2002 design with existing Mississippi designs will also be made to develop an engineering feel for the new design approach.

6.2.3 Evaluate Suitability of National Performance Models for Mississippi

The performance indicators considered for hot mix asphalt (HMA) pavements are smoothness (or ride quality), load-associated top-down and bottom-up fatigue cracks, rutting

or distortion, and thermal cracks. Additionally, in semi-rigid pavements, fatigue cracking in the high-strength stabilized base is also considered. For PCC pavements, smoothness or ride quality, fatigue cracking of slabs, and joint faulting of jointed plain concrete pavements (JPCP) and punchouts for continuously reinforced concrete pavements (CRCP) are considered performance indicators. These performance indicators exist for new or reconstructed designs and for overlay designs.

The research will compare the data (pavement types, climate, soils, designs, etc.) used to calibrate the national performance models with those required for Mississippi conditions. Significant differences between the Mississippi and national factors will indicate the need for further validation of the national models to meet Mississippi needs, and identify those inputs that need the most attention.

6.2.4 Establish Materials and Traffic Estimation Procedures and Default Values

Procedures will be developed to estimate the required material inputs for the new Design Guide. This will require an analysis of Mississippi's databases. These results will be analyzed and placed into the proper formats for use in the 2002 Design Guide as defaults.

We will also review the procedure developed to estimate the required traffic inputs for the new Design Guide for roadways falling under various functional classes and truck traffic classification groups around the State. This will involve a review of Mississippi's WIM and other traffic data at a selected number of sites to cover the State. These results will be analyzed and placed into the proper formats for use in the 2002 Design Guide as defaults.

6.2.5 Complete Design Guide Software Sensitivity Analysis

The sensitivity analysis of the Design Guide software will be completed and will cover the full range of inputs, including mix proportions, design features, traffic loading, environmental zones, subgrade types, design reliability, and other variables required in the design process. Pavement layer thicknesses or other parameters of interest to Mississippi DOT (e.g., pavement performance indicators) will be used as a basis for comparison. This effort will enable a deeper understanding of the 2002 Design Guide procedures and will help fine tune plans for the types and extent of laboratory and field testing, the amount of performance data required for performance prediction, etc.

6.2.6 Set Up Laboratory and Field Testing Program

A laboratory and field testing program will be set up to obtain pavement and foundation layer properties that will represent the range of mixes, materials, and site conditions around the state. All testing will be performed as specified by the 2002 Design Guide. All field and laboratory testing will be the responsibility of the Mississippi DOT, and the project team will review the results. Burns Cooley Dennis, Inc. (BCD) will conduct laboratory tests as required by Mississippi DOT. Laboratory testing will establish default material libraries for support (base/subbase) and foundation (subgrade) layers.

6.2.7 Finalize the Selection of Pavement Sections

A sampling plan (factorial experiment design) was developed as part of the Phase I research. The factorial experiment design considered factors affecting flexible pavement performance in Mississippi and established levels for experiment design. Appropriate pavement and rehabilitation types, designs, subgrades, climates, and traffic to cover the conditions of interest in Mississippi are included in the experiment design. A similar plan will be developed for rigid pavements in Phase II. In-service original (non-overlaid) pavement sections and overlaid sections will be selected for use in the distress model calibration. These sections will include Mississippi LTPP and other research projects, and possibly other sections that will need to be surveyed and the 2002 design inputs measured. Mississippi LTPP sections meeting the factorial experiment design requirements were shown in Chapter 3. Missing sections could be filled with sections from adjacent states, if desired. Mississippi test sections from the LTPP program and other Mississippi research efforts or pavement management files will be used to fill the cells as possible. All 2002 design inputs will be either estimated or measured for these sections. The performance data collected for these sections will be examined for completeness and compatibility with the original calibration effort.

6.2.8 Prepare and Submit Phase II Interim Report

The first seven tasks will be completed in 18 months; laboratory testing to set up material libraries will continue through most of the project. A draft report documenting the research results and providing details of the research plan for the next 30 months will be

prepared. The draft interim report will be submitted at the end of the 16th month after the notice to proceed.

6.2.9 Assemble Data for Calibration and Validation of Performance Models

Though the appropriate Mississippi LTPP sections have been identified during Phase I, many cells of the factorial experiment design remain empty. These will be filled using sections from the Mississippi DOT PMS, and some new sections may have to be set up. However, for each test section in the factorial experiment design shown in Table 3.4, a number of steps will be required to obtain appropriate data for calibration and validation of the performance models. These steps include:

- Obtain and review data related to pavement structure, construction materials, current and design traffic, and climate
- Supplement any missing data from construction reports, specifications; report any unobtainable data to Mississippi DOT
- Obtain and review monitoring data from the databases (history, distress, deflection, and profile)
- Estimate initial values for selected properties
- Determine model input from initial property values

The level of effort associated with obtaining appropriate data will vary for the four types of test sections. The final number of different sections is uncertain at this time, we have estimated the unit cost of activities associated with each type of test section.

6.2.10 Backcalculation of FWD Data on Rehabilitation Sections

FWD deflection data will be used to determine the layer properties of rehabilitation sections included in the work plan. Mississippi DOT will conduct FWD tests and provide ERES the necessary deflection and layer thickness data to estimate the moduli of pavement layers.

6.2.11 Calibration and Validation of Performance Models

Performance data from Mississippi pavements will be used along with the 2002 software to carry out the calibration and validation of the Design Guide performance models.

This task will include determining the field performance for each section in the calibration database and a comparison with the performance predicted using the 2002 Design Guide software. Predicted distress (e.g., cracking, rutting, joint faulting) will be plotted against measured or observed distress for these sections and the adequacy of the models determined. Adjustments to the calibration constants will be obtained to incorporate into the 2002 software for use in designing Mississippi pavements and rehabilitation.

6.2.12 Recommend Levels Needed for Design Inputs

A recommended level (1, 2, or 3) will be selected for each design input to achieve a desirable precision needed to obtain a valid design. This will also include a recommendation on the testing protocols needed to acquire data. Specific problems in obtaining proper input data and recommended potential solutions to these problems will be identified. Default values will be proposed for all input variables used in Level 3, and acceptable ranges for all inputs will be confirmed.

6.2.13 Evaluate Design Results Using Locally Calibrated Models

An evaluation will be conducted of the results of new and rehabilitation designs using locally calibrated and validated performance models with respect to the three input levels. This will include a comparison of the new design results with the existing design methods utilized by Mississippi DOT over a desired range of site conditions (traffic, subgrade, climate and existing pavement to be rehabilitated). Variables will be identified and sensitivity of each determined on the design parameters with emphasis on surfacing thickness (HMA and PCC).

6.2.14 Develop Training Materials and Conduct Training for DOT Personnel

Existing training materials (i.e., those developed under NCHRP 1-37A) will be adapted or modified for training options selected in consultation with the Mississippi DOT. The training materials will include training courses/seminars and manuals. These will be structured to address needs at all levels, both within and outside the Mississippi DOT, including high-level managers, engineers, and field/laboratory technical personnel.

ERES will also conduct training sessions as required to meet the needs of the Mississippi DOT. The DOT may decide to conduct all training sessions at a central location or at various regional offices.

6.2.15 Customize the 2002 Design Guide Software

Under this task, the 2002 Design Guide software can be customized for Mississippi DOT use. This task will aid in the uniform application of the 2002 Design Guide program throughout the state. For example, soils and materials libraries will be created along with default values and tables, traffic libraries will be established to select default traffic inputs (including volumes, weights, and adjustments) based on roadway functional class or broad traffic stream descriptions, finalized local calibration coefficients or functions will be programmed into the software, and so on.

6.2.16 Prepare and Submit Final Project Report and Design Manual

A final project report that documents all aspects of the work conducted during Phase II of the research will be prepared.

ERES will also prepare a design manual with step-by-step instructions on how to perform design using the 2002 Design Guide for the Mississippi DOT conditions. The manual will describe the selection of inputs for new or rehabilitation designs for HMA and PCC pavements (defaults and ranges for Mississippi), desired hierarchical levels for each input and the procedures to be followed to obtain the inputs, selection of performance criteria and associated reliability levels for each pavement type and roadway functional class, and so on.

6.3 PHASE II SCHEDULE

Phase II will last for four fiscal years and will include all work necessary to implement the 2002 Design Guide for the Mississippi DOT. The tentative project schedule is shown in Figure 6.1. The schedule also includes 11 meetings held at strategic points during Phase II. These meeting are scheduled such that they coincide with the beginning and completion of major project tasks and thus provide an opportunity to discuss the plans and results of major project activities, respectively. A meeting each is also planned when

submitting the draft interim and final project reports. The final project meeting is scheduled at the time of submission of the final project report.

6.4 PHASE II BUDGET

The estimated budget to conduct Phase II work is \$800,000; the estimated fiscal year costs are:

- FY 04: \$125,000
- FY 05: \$200,000
- FY 06: \$200,000
- FY 07: \$200,000
- FY 08: \$75,000

These total costs include \$250,000 for laboratory testing of base and subgrade materials. Mississippi DOT will be responsible for coordinating and conducting all laboratory and field testing. The budget includes the costs associated with providing guidance to set up a laboratory and field testing program and to review the results. The estimated costs do not include costs to set up new test sections.

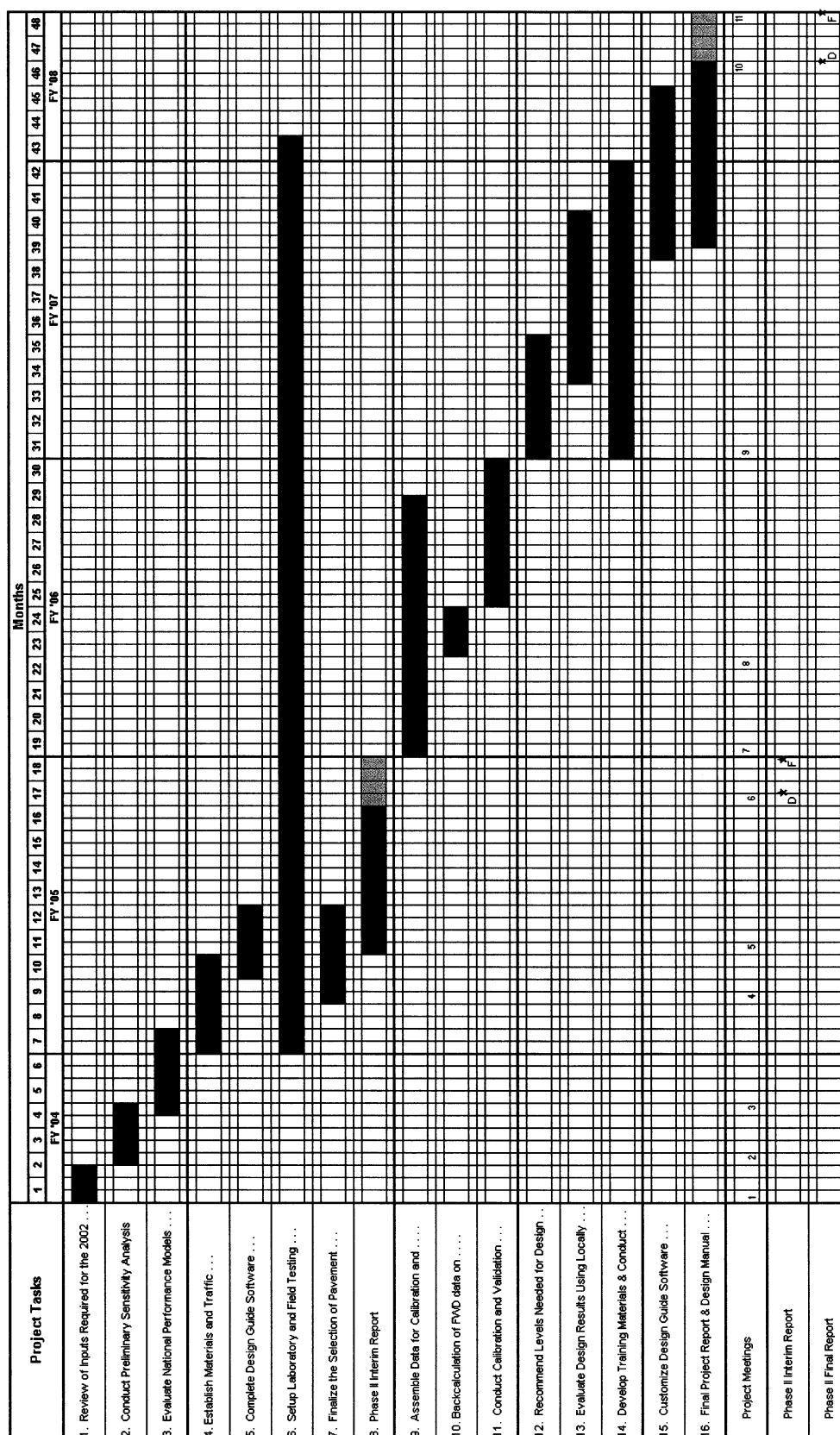


Figure 6.1. Proposed project schedule for Phase II.

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CHAPTER 7

PROJECT SUMMARY AND RECOMMENDATIONS

7.1 PROJECT SUMMARY

There are many benefits associated with implementing the 2002 Design Guide. The principal economic savings result from more cost-effective and reliable designs. Systematically integrating climate factors, material properties, construction variability, and traffic loads during the pavement design process allows State DOTs to better predict pavement performance. Roadway users also benefit from fewer pavement closures due to premature failures and a better ride quality during the life of the pavement.

To realize these benefits, the Mississippi DOT has taken a proactive approach to implement the 2002 Design Guide. However, a well-thought out plan is necessary for smooth implementation of the new design procedure. This report describes the results of research conducted to develop a 2002 Design Guide implementation plan for Mississippi. The following research activities were conducted:

- Familiarized Mississippi DOT personnel with the 2002 Design Guide by holding several meetings
- Identified Mississippi DOT needs relative to the types of pavements of interest for new or reconstruction design and the types of rehabilitation for existing pavements
- Developed a calibration and validation plan to modify the 2002 Design Guide performance models for Mississippi conditions
- Developed a factorial experiment design to select test sections for calibration and validation of performance models for Mississippi conditions
- Recommended technology transfer procedures and a personnel training program for Mississippi DOT
- Prepared a Phase II work plan for implementation of the 2002 Design Guide for Mississippi DOT

- Estimated costs associated with implementation of the 2002 Design Guide for Mississippi DOT

The implementation plan developed for Phase II is to be carried out over five fiscal years and describes activities that would be necessary for smooth transition from the current pavement design procedure to the 2002 Design Guide procedure. Implementation plan activities can be grouped as follows:

- Preliminary Analysis
 - Review all inputs and select procedures for obtaining them
 - Conduct cursory verification of 2002 Design Guide by conducting a preliminary sensitivity analysis
 - Evaluate suitability of national performance models for Mississippi conditions
- Complete Sensitivity Analysis
 - Establish materials and traffic default values and input estimation procedure
 - Help set up a laboratory and field testing program
 - Conduct a comparison (sensitivity analysis) between Mississippi DOT and 2002 Design Guide designs
- Performance Model Calibration and Validation
 - Finalize the pavement section sampling plan
 - Assemble data needed for calibration and validation of performance models
 - Carry out the calibration and validation of performance models
- Evaluation of Calibrated and Validated Performance Models
 - Recommend levels of input need for design
 - Conduct a sensitivity analysis using Mississippi calibrated and validated models for different input levels
- Implementation Tools
 - Adapt 2002 Design Guide for Mississippi
 - Develop and conduct training for Mississippi personnel
 - Customize 2002 Design Guide software (provide local calibration factors)
 - Prepare final project report

7.2 RECOMMENDATIONS

Developing an implementation plan is an important step towards successful implementation of the 2002 Design Guide in Mississippi. The following recommendations could further expedite the process and lead to a smooth transition from the current procedure to the 2002 Design Guide procedure:

- Familiarize upper management with the benefits of the 2002 Design Guide to gain their support
- Set up a core group of Mississippi DOT engineers from various divisions that would champion the implementation of the new procedure
- Carry out calibration and validation of performance models to attune the resulting pavements designs to Mississippi conditions
- Set up a laboratory test program to develop default material input libraries
- Develop an input estimation procedure and set up levels of input
- Develop training materials and carry out training of Mississippi DOT personnel for smooth implementation

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CHAPTER 8

REFERENCES

1. 2002 Design Guide for Design of New and Rehabilitated Pavement Structures, Draft Final Report. ERES Consultants Division of Applied Research Associates, Inc., Champaign, Illinois, December 2002.
2. The 2002 Design Guide – The Road to Better Performing Pavement, Introductory CD-ROM. ERES Consultants Division of Applied Research Associates, Inc., Champaign, Illinois, December 2002.
3. Saeed, Athar, and Jim W. Hall, Jr., *Develop Mississippi DOT's Plan to Implement the 2002 Design Guide*, Proposal Prepared for the Mississippi Department of Transportation. ERES Consultants Division of Applied Research Associates, Inc., Vicksburg, Mississippi, June 5, 2002.
4. Schwartz, Charles, and Mohamed El-Basyouny, "Flexible Pavement Design and Rehabilitation Procedure," Presentation made at the 2002 Transportation Research Board Annual Meeting, Washington, DC, January 12, 2003.
5. Long Term Pavement Performance Program. Federal Highway Administration, U.S. Department of Transportation. <http://www.tfhr.gov/pavement/ltp/ltp.htm>, web document accessed July 14, 2003.
6. Description of GPS Experiments. Federal Highway Administration, U.S. Department of Transportation. <http://www.tfhr.gov/pavement/ltp/gps.htm>, web document accessed July 14, 2003.
7. Description of SPS Experiments. Federal Highway Administration, U.S. Department of Transportation. <http://www.tfhr.gov/pavement/ltp/sps.htm>, web document accessed July 14, 2003.
8. Obtaining LTP Data. Federal Highway Administration, U.S. Department of Transportation. <http://www.tfhr.gov/pavement/ltp/getdata.htm>, web document accessed July 14, 2003.

9. LTPP Data Base. Federal Highway Administration, U.S. Department of Transportation. <http://www.datapave.com>, web document accessed July 14, 2003.
10. LTPP Southern Region, Federal Highway Administration, U.S. Department of Transportation. <http://www.bre.fugro.com/ltp/>, web document accessed July 14, 2003.
11. Mississippi GPS Test Sections, Federal Highway Administration, U.S. Department of Transportation. <http://www.bre.fugro.com/ltp/html/gpsMS.htm>, web document accessed July 14, 2003.
12. Mississippi SPS Test Sections, Federal Highway Administration, U.S. Department of Transportation. <http://www.bre.fugro.com/ltp/html/spsMS.htm>, web document accessed July 14, 2003.
13. Hajek, Jerry J., and Olga I. Selezneva, *Estimating Cumulative Traffic Loads*, Final Report for Phase I. FHWA-RD-00-054, Federal Highway Administration, McLean, Virginia, July 2000.
14. *Milestones 2002 – Moving Towards the Pavement Design Guide*, Winter 2001 issue. National Research Council, Transportation Research Board, 2001.
15. Buchanan, Shane, *Traffic Load Spectra Development for the 2002 AASHTO Design Guide*, Research Needs Statement Prepared for the Mississippi Department of Transportation. Department of Civil Engineering, Mississippi State University, Starkville, Mississippi, July 12, 2002.
16. Larson, G, and Berry J. Dempsey, Integrated Climatic Model – Version 2.0. Report No. DTFA MN/DOT 72114. University of Illinois at Urbana- Champaign, Illinois, 1997.
17. *Milestones 2002 – Moving Towards the Pavement Design Guide*, Fall 2002 issue. National Research Council, Transportation Research Board, 2002.